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TITLE: THERMAL RESPONSES DURING EXTENDED WATER IMMERSION: COMPARISONS OF REST AND EXERCISE, AND LEVELS OF IMMERSION

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Fourteen male volunteers participated in Phase 1 of the project. Prior to experimental tests, subjects completed a medical evaluation and were cleared for testing by a physician, and performed body composition and maximal aerobic power tests on both a treadmill and bicycle ergometer. Mean age, height and weight of the group were 25.0 yr, 176.0 cm and 76.6 kg, respectively. Three groups of subjects were formed on the basis of body composition analysis. The mean % body fat values were 9.5 for the low-fat group (L, N=5), 14.8 for the moderate-fat group (A, N=5), and 19.6 for the high-fat group (H, N=4); maximal aerobic power on the treadmill and bicycle ergometer was 4.6 l/min and 3.98 l/min for L, 4.31 l/min and 3.68 l/min for A and 4.32 l/min and 3.68 l/min for H, respectively. Following preliminary evaluation, subjects were immersed in water on four occasions (two temperatures X two activities) for durations up to 3 h. Water temperatures were based on an assumed equivalent thermal strain (T_w, L 26, A 22, H 18 deg C) and on identical thermal stress (T_w 24 degC)

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19. (con't) with both resting and exercise (approximately 35-40% of peak oxygen uptake) conditions included for each temperature. During resting conditions at equivalent thermal strain rectal (T_{re}) and esophageal (T_{es}) temperatures declined in all groups over the immersion period (ΔT_{re}, -1.32, -1.45, and -1.32 deg C; ΔT_{es}, -0.47, -0.43, and -0.60 deg C for L, A and H subjects, respectively). During exposures at 24 deg C T_{re} and T_{es} dropped moderately in the L(ΔT_{re} -1.67, ΔT_{es} -0.53 deg C) and modestly in the A (ΔT_{re} -1.04, ΔT_{es} -0.15 deg C) and H(ΔT_{re} -0.18, ΔT_{es} -0.70 deg C) throughout the 3-h exposure. The decline in both T_{re} and T_{es} was non-linear with the major decline in core temperatures occurring within the first 1.5-2.5 h of immersion followed by stabilization thereafter. Skin temperature responses were not outstanding and appeared to follow T_w. During exercise T_{re} and T_{es} values were higher compared to rest for all groups in all T_w. Minimal changes in T_{es} were noted across time and the differences observed between T_{re} and T_{es} at rest were not evident when no change or a slight increase in core temperatures was observed.

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Michael M. Jone 4/2/90

PI Signature Date

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INTRODUCTION

Limited information is available as to the time course of Tre during cold-water immersion. The preponderance of literature concerned with the physiological responses has utilized immersion exposures for durations between 20 and 90 min (3,4,5,7,8,9,14,16). In order to relate this literature to longer exposure times in cold water, one must assume that the drop in Tre beyond the reported final values is linear or at least follows an extrapolation of the pattern observed during the immersion period. In one report, Hayward et al. (5) developed a prediction equation that linearly extrapolated Tre values obtained during a 40 min exposure to a duration that represented a Tre of 30 deg C (operationally defined as "incipient" death (5)).

Clearly, this procedure assumes that the fall in Tre during cold water exposure follows a linear pattern as duration progresses. This assumption of linearity though supported in very cold water (1) would be questionable in warmer temperatures in light of several studies (2,6,11, 15). In reporting the unpublished data of Spealman, Molnar (11) described the linear reduction in Tre up to 60 min of immersion, in water temperatures above 20 deg C, however, Tre leveled off as the duration of immersion progressed. Cannon and Keatinge (2) also observed that individuals were able to stabilize Tre at values below 36 deg C during prolonged immersion. Subsequent work (6) indicated that individuals could eventually stabilize Tre in water as low as 5 deg C.

The present study examined the thermoregulatory adjustments of individuals exposed to cold water for durations up to 3 h. Special consideration was given to the influence of body fat, water temperature and level of activity on these adjustments.

BODY

METHODS

Subjects

Fourteen (14) male subjects with a mean age, height and weight of 25.0 yr, 176.0 cm and 76.6 kg, respectively, were recruited from the college community. Each individual completed an examination which included medical history, physical examination, blood and urine chemistries and resting electrocardiogram and cleared for maximal exercise and cold water immersion by a board-certified emergency medicine physician. All subjects were informed of the nature of the study, as well as the risks and benefits of participation in the testing procedures. Participants were free to withdraw their consent at anytime during the testing. One subject from low fat group withdrew from a cold water exposure prior to reaching the core-temperature limit established by the protocol. Three subjects did not have esophageal temperature measured, two of which (both from A) had mild episodes of vaso-vagal syncope during the probe's placement, while one (from high fat group) did not attempt the procedure.

The subjects were divided into three groups based on body fatness. Individuals in the low fat group (L) (N=5) averaged 9.5 % body fat, whereas the average (A) and high fat (H) groups averaged 14.8 and 19.6 %, respectively.

Procedures

Two pre-experimental tests were performed by all subjects prior to immersion tests. These included body composition analysis by

hydrostatic weighing and peak aerobic power tests in air on both a cycle ergometer and treadmill. During the ergometer test the subject pedals initially at 50 W for 2 min. Exercise intensity is increased 30 W every 2 min until the subject can no longer maintain the 60 rpm pace. During the treadmill test, subjects performed 10 min of walking at 3.2 mph at a 10% elevation as a warmup. This was immediately followed by a continuous, graded protocol to volitional exhaustion where the subject ran at 6 mph at 0% for 2 min followed by increasing elevation of 2.5 % every 2 min.

Following assessment of body fat and peak aerobic power, subjects performed four (4) experimental test. For each test the subject was immersed to the manubrium sternum for a duration of 3 h. The four tests included immersion in two water temperatures with both rest and exercise conditions; each performed on separate days. The water temperatures were 18 and 24 deg C for H (one less fat subject was immersed in 20 rather than 18 deg C), 22 and 24 deg C for A and 24 and 26 deg C for L. Therefore, comparison between groups were made at an equal thermal stress (ST)(24 deg C for H, A and L) and at an equivalent thermal strain (SN)(18 deg C for H, 22 deg C for A and 26 deg C for L).

One hour prior to each immersion test subjects arrived at the laboratory dressed in nylon swim suits and were harnassed for temperature and heat-flow measures. Twenty minutes prior to immersion subjects sat quietly in air between 25 and 28 deg C for determination of control values for esophageal (Tes), rectal (Tre) and mean-weighted skin (Tsk) temperatures, mean heat flow (Hc) and oxygen uptake (VO2). During the resting experiments subjects remained in a seated position in water for a 3-h period. During exercise conditions subjects pedalled an

ergometer designed for use in water (12). Exercise utilized the legs and continued for a 3-h period. Power output adjustments were made during the initial 15 min of exercise so as to achieve the correct exercise intensity for the individual which approximated 35 % of the peak aerobic power obtained on the bicycle test in air. During all immersion tests Tsk, Tre, Tes, Tw, Ta, and Hc were determined and stored every 2 min, whereas VO2 was recorded every min. Also, throughout immersion the subjects rated their thermal sensation and during exercise their perception of effort; these measures coincided with the recording of thermal data.

Measurements and Equipment

Body composition. Body volume was determined by the technique of hydrostatic weighing. Pulmonary residual lung volume was measured in the bent forward body position just prior to water immersion by the use of an oxygen dilution technique. Body weight in air was measured on a Chatilion scale accurate to the nearest 50 g. Body fat was determined from body density by the use of a formula derived by Siri (13).

Thermal and metabolic assessments. Measurements of Tsk were obtained by the use of a five-point thermocouple harnass, where Tsk was determined by an area-weighting formula as follows: Tsk = 0.22 T calf + 0.28 T thigh + 0.28 T chest + 0.08 T triceps + 0.14 T forearm. Thermistors (YSI, Ohio) were covered with one layer of tape (Hy-tape, New York). Air and forehead temperatures were also recorded. Tre was recorded by the placement of a probe 10 cm into the rectum and held in place by a 1.1 cm diameter ball attached to the probe. Direct

assessment of heat loss was determined by 5 heat flow sensors taped adjacent to the skin thermistors.

Oxygen uptake (VO2) was determined by open-circuit spirometry where the inspired volumes are measured by a Parkinson-Cowen CD-4 gasmeter. Samples of expired air were taken from a seven-liter mixing chamber and analyzed for oxygen (Applied Electrochemistry S-3A) and carbon dioxide (Ametek CD-3A). All volumes were corrected to standard conditions for determination of VO2. Metabolic Rate (M) was calculated from VO2 (18).

Immersion tank and data acquisition. Subjects were immersed in a 2000 gallon tank of water. The water was filled to a depth of the manubrium sternum and continuously circulated by the use of a pool filter. Temperature was controlled within +/- 0.5 C. All temperature and heat flow data were recorded and stored on a Hewlett-Packard (HP) 3056 DL Data Acquisition System that included an HP 3421 Data Acquisition/Control Unit and an HP 85 B computer.

RESULTS

Maximal metabolic and cardiovascular responses of the L, A, and H groups to treadmill exercise are reported in Table 1. The L group's maximal oxygen uptake averaged 4.6 l/min which represented 62.1 ml/min per kg of body weight. In contrast to L, both the A and H groups averaged about 4.3 l/min with the relative-to-body weight maximal oxygen uptakes of 57.0 and 49.1 ml/kg*min for A and H, respectively. Maximal pulmonary ventilation, respiratory exchange ratio (R) and heart rate were within normal limits for all subjects. Table 2 illustrates the maximal metabolic and cardiorespiratory responses of the groups to bicycle ergometer exercise. Despite the somewhat lower values on the

bicycle ergometer compared with treadmill for all groups, the contrasts between groups during cycling were similar to those observed during treadmill exercise with responses of L slightly higher than both A and H groups.

Table 3 shows the oxygen uptake values across time during resting conditions in water at temperatures that provide equivalent thermal strain (SN) and equal thermal stress (ST) to the L, A and H groups. Compared to pre-immersion values the still oxygen uptake values were somewhat higher during immersion in the SN condition, though the increase was consistent among the differing body fat groups. During the ST condition the oxygen uptake values increased proportional to the level of body fatness of each group. That is, minimal changes in oxygen uptake were seen in the H group during immersion compared with the air control condition, whereas there was a noted two to three fold increase in rate above the level established by the pre-immersion condition in L.

Table 4 illustrates the oxygen uptake values during exercise in water during SN and ST conditions. During exercise in water oxygen uptake values were higher than pre-immersion rest values for all three groups. The values approximated 1.4 lO2/min for each group across time in the ST condition. Similar results were evident during exposure of all groups to water at 24 deg C; though for the L group, there was a slight increase in the rate of oxygen usage across the three hour immersion period.

Pulmonary ventilation during resting conditions is shown in Table 5. Prior to immersion in the SN condition the ventilation was approximately 9.0 l/min for all subjects. During immersion the ventilation increased slightly during the first 30 min and reached

levels of 1.5 to 2 times the pre-immersion values during mins 60 to 180. During the ST condition the pulmonary ventilation the pre-immersion values for all groups were approximately 8.5 l/min. During immersion the ventilation was increased in all groups though the magnitude of increase was indirectly related to the level of body fatness with the greatest increase observed in the L group and the least increase in H.

Table 6 shows the pulmonary responses to exercise during 3-h immersion in ST and SN conditions. Pre-immersion values were approximately 9 l/min during ST and increased to levels between 26 and 31 l/min during exercise. These values were maintained during the 180 min of immersion. In the exercise and SN condition the pulmonary ventilations were similar to ST with values ranging from 28 - 34 l/min throughout the immersion period with the higher values recorded by the L group.

Rectal temperature values during rest in SN and ST conditions are shown in Table 7. Prior to immersion in the SN condition Tre values were approximately 37.1 deg C and declined in all groups throughout 3 h of immersion. Similar declines in Tre were noted between the groups throughout the exposure period. Tre declined in all groups over the immersion period (ΔTre, - 1.32, -1.45, and -1.32 deg C for L, A and H subjects, respectively). During ST conditions Tre dropped moderately in the L (ΔTre -1.67 deg C) and A (ΔTre -1.04 deg C) groups and modestly in the H group (ΔTre -0.18 deg C) throughout the 3-h exposure. The decline in Tre was non-linear with the major decline in core temperatures occurring within first 2.0-2.5 h of immersion followed by a stabilization thereafter.

During exercise Tre values were higher compared to rest for all groups in all Tw (Table 8). During the SN condition the Tre responses were not the same for all groups. In the L group Tre declined modestly during the first 30 min and remained at about 36.8 deg C for 2.5 h. Tre responses of the A group followed a similar pattern though the stabilized temperature was 36.5 deg C, somewhat lower than the L group. In contrast to these responses the H group demonstrated a slight increase throughout the first h of immersion followed by a consistent decline throughout the last 2 h, dropping to 36.58 deg C by the end of the exposure. It appeared that equivalence in thermal strains was not achieved in the present study during exercise conditions. During ST the responses of the L and A groups appeared to be similar. Tre declined during the first 30 min, followed by Tre stabilization throughout the remainder of the exposure. The H group showed an increase in Tre during the first 30 min and the Tre remained elevated for the final 2.5 h.

Table 9 shows the Tes responses during rest. In the SN condition Tes declined in all groups over the immersion period (ΔTes, -0.47, -0.43, and -0.40 deg C for L, A and H subjects, respectively). During the ST condition Tes dropped modestly in L (ΔTes -0.53 deg C), A (Tes -0.15 deg C) and H (ΔTes -0.70 deg C) throughout the 3-h exposure. The decline in Tes was also not linear with the major decline occurring within first 1.0-1.5 h of immersion followed thereafter by stabilization. During exercise Tes values were higher compared to rest for all groups in all Tw (cf. Tables 9 and 10). Minimal changes in Tes were noted across time. The differences observed between Tre and Tes at rest were not evident when no change or a slight increase in core temperatures was observed.

Skin temperature responses were not outstanding and appeared to be strongly influenced by Tw.

CONCLUSIONS

The factors that contribute to the variation in core temperature response during cold-water immersion include body composition (9,10), water temperature (16), type and level of activity (17), and gender (9,10). Limited information is available, however, as to the thermoregulatory response in relation to the duration of exposure. Most studies have utilized immersion exposures for durations up to 90 min (3,4,5,7,8,9,14,16). Presently, the available literature has not adequately detailed the metabolic and thermal adjustments of individuals exposed to longer immersion times in cool and cold water. Hayward et al. (5) using very cold water linearly extrapolated Tre values obtained during a 40 min exposure to the point when Tre dropped to 30 deg C. This approach assumes that the fall in Tre during exposure follows a linear pattern as duration progresses. This assumption of linearity, though supported in very cold water (1), would be questionable in warmer temperatures in light of several studies (2,6,11,15).

The present study of the physiological adjustments during prolonged exposures may help clarify thermoregulatory dynamics during cold-water stress. The time course of rectal and esophageal temperature adjustments to exposures to water at temperatures above 18 deg C appears to be non-linear over a 3-h period. In water temperatures that were equivalent in thermal strain on the body (i.e., 18 for H, 22 for A and 26 deg C for L) or equal in the thermal stress provided by the water (i.e., 24 deg C for L, A and H) for all groups, the responses of both the rectal and esophageal temperatures showed a trend toward

stabilization of temperatures within the 3-h period. In fact it appears that Tes stabilized at an earlier point in time compared with Tre during all resting conditions in cold water.

In addition to the observed stabilization of the core temperatures throughout the three hour period, there appears to be noticeably higher values of the Tes compared with Tre at stabilization. The higher Tes may reflect a greater chest core temperature compared with abdominal core during exposure to cool and cold water. This result was most obvious in the leaner subjects compared with the fatter, and during rest compared with exercise conditions. Based upon the presently available data, it is difficult to describe the underlying physiological and thermoregulatory mechanisms responsible for such adjustments. Additional analyses of the present data and further research are required to determine these mechanisms and the implications of the present findings on survival prediction of man exposed to cold water.

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Table 1. Maximal metabolic and cardiorespiratory responses of the low, average and high body fat groups to treadmill exercise .

Group	Low	Average	High
Maximal Oxygen Uptake (l/min)	4.60 .20	4.31 .40	4.32 .24
Maximal Oxygen Uptake (ml/kg*min)	62.1 5.6	57.0 4.4	49.1 3.6
Maximal Heart Rate (beat/min)	201 9	195 5	199 17
Maximal Pulmonary Ventilation (l/min,BTPS)	154.9 15.7	146.6 26.6	150.9 20.7
Maximal R	1.15 .05	1.12 .14	1.19 .01

values are means and standard deviations

Table 2. Maximal metabolic and cardiorespiratory responses of the low, average and high body fat groups to bicycle ergometer exercise.

Group	Low	Average	High
Maximal Oxygen Uptake (l/min)	3.98 .69	3.68 .49	3.68 .29
Maximal Oxygen Uptake (ml/kg*min)	55.4 2.6	51.9 6.2	43.2 3.1
Maximal Heart Rate (beat/min)	188 8	188 9	191 16
Maximal Pulmonary Ventilation (l/min,BTPS)	152.7 21.6	143.9 12.3	150.9 20.8
Maximal R	1.19 .21	1.10 .15	1.10 .09

values are means and standard deviations

Table 3. Oxygen uptake values during rest in water at equivalent thermal strain (A) and equal thermal stress (B) for low, average, and high body fat groups.

A

	Tw	N	PRE	30	60	90	120	150	180
LOW	26	5	.33	.54	.67	.74	.70	.62	.73
			.08	.27	.14	.14	.13	.06	.25
						*	*	*	*
AVERAGE	22	5	.30	.43	.66	.66	.76	.78	.77
			.05	.13	.19	.08	.10	.11	.09
									*
HIGH	18	4	.38	.58	.82	.69	.99	.76	.78
			.07	.13	.07	.08	.23	.04	.09

B

	Tw	N	PRE	30	60	90	120	150	180
							*	*	*
LOW	24	5	.32	.62	.70	.85	.96	.85	.84
			.06	.17	.21	.14	.23	.10	.17
						*	*	*	*
AVERAGE	24	5	.33	.53	.60	.76	.72	.64	.55
			.05	.13	.16	.13	.12	.10	.06
HIGH	24	4	.32	.36	.52	.57	.54	.61	.56
			.02	.03	.15	.08	.06	.08	.07

values are means and standard deviations; Tw is water temperature;
* N=N-1

Table 4. Oxygen uptake values during exercise in water at equivalent thermal strain (A) and equal thermal stress (B) for low, average, and high body fat groups.

A

	Tw	N	PRE	30	60	90	120	150	180
LOW	26	5	.33	1.33	1.38	1.42	1.52	1.33	1.36
			.04	.25	.19	.18	.37	.2	.18
AVERAGE	22	5	.32	1.39	1.48	1.56	1.52	1.54	1.46
			.02	.21	.16	.30	.19	.22	.20
HIGH	18	4	.36	1.37	1.44	1.44	1.49	1.42	1.52
			.04	.15	.11	.03	.04	.10	.16

B

	Tw	N	PRE	30	60	90	120	150	180
LOW	24	5	.32	1.43	1.56	1.55	1.62	1.65	1.75
			.06	.18	.27	.22	.27	.33	.40
AVERAGE	24	5	.34	1.42	1.42	1.46	1.50	1.43	1.51
			.08	.22	.26	.23	.16	.23	.23
HIGH	24	4	.31	1.34	1.38	1.32	1.38	1.32	1.42
			.01	.16	.21	.24	.18	.09	.08

values are means and standard deviations; Tw is water temperature;
* N = N-1

Table 5. Pulmonary ventilation values during rest in water at equivalent thermal strain (A) and equal thermal stress (B) for low, average, and high body fat groups.

A

	Tw	N	PRE	30	60	90	120	150	180
LOW	26	5	8.14	10.38	12.7	15.94	13.79	13.59	14.24
			1.54	4.14	2.66	3.18	2.49	1.94	3.60
						*	*	*	*
AVERAGE	22	5	8.71	11.02	16.04	15.74	15.67	18.86	16.42
			1.62	2.53	5.37	3.95	1.84	4.01	3.24
HIGH	18	4	9.64	12.58	16.27	14.05	20.17	15.22	15.6
			.52	3.74	.48	2.40	6.66	.90	2.26

B

	Tw	N	PRE	30	60	90	120	150	180
							*	*	*
LOW	24	5	8.38	12.29	14.66	17.83	18.28	15.94	15.72
			1.17	2.77	3.25	1.48	3.42	1.44	3.07
						*	*	*	*
AVERAGE	24	5	8.66	14.12	13.55	16.78	16.32	14.87	14.29
			.89	6.58	2.03	1.20	3.22	1.90	3.50
HIGH	24	4	8.56	7.77	10.84	11.98	11.55	12.67	11.83
			1.18	1.46	3.41	1.26	1.28	1.54	2.00

values are means and standard deviations; Tw is water temperature;
* N = N-1

Table 6. Pulmonary ventilation values during exercise in water at equivalent thermal strain (A) and equal thermal stress (B) for low, average, and high body fat groups.

A

	Tw	N	PRE	30	60	90	120	150	180
LOW	26	5	8.50	26.49	27.06	28.30	31.14	26.54	26.76
			0.14	2.27	2.69	4.46	8.57	3.79	3.86
AVERAGE	22	5	8.19	28.82	29.06	31.33	30.46	30.20	29.15
			0.66	6.07	5.29	5.91	5.36	5.00	5.24
HIGH	18	4	10.50	31.40	30.35	30.98	30.12	28.36	29.33
			0.19	2.61	4.36	1.39	2.34	3.24	3.30

B

	Tw	N	PRE	30	60	90	120	150	180
LOW	24	5	8.06	29.22	30.40	31.28	32.02	32.28	34.05
			1.39	4.69	5.95	5.79	7.25	8.16	8.75
AVERAGE	24	5	9.61	30.45	29.79	29.65	30.03	29.02	30.20
			2.73	5.48	6.82	5.38	4.52	4.39	4.60
HIGH	24	4	8.84	28.38	29.34	28.36	28.58	27.60	28.98
			1.26	5.10	5.30	6.14	5.20	2.30	3.92

values are means and standard deviations; Tw is water temperature;
* N = N-1

Table 7. Rectal temperature values during rest in water at equivalent thermal strain (A) and equal thermal stress (B) for low, average, and high body fat groups.

A

	Tw	N	PRE	30	60	90	120	150	180
LOW	26	5	37.11	36.88	36.35	36.16	36.01	35.84	35.79
			.17	.15	.26	.37	.29	.27	.35
							*	*	*
AVERAGE	22	5	37.12	36.67	36.10	35.74	35.70	35.63	35.57
			.11	.41	.62	.55	.3	.16	.16
									*
HIGH	18	4	37.08	36.88	36.35	35.98	35.72	35.30	35.86
			.27	.26	.48	.65	.83	1.00	.34

B

	Tw	N	PRE	30	60	90	120	150	180
							*	*	*
LOW	24	5	37.09	36.89	36.43	36.03	35.75	35.55	35.42
			.22	.24	.32	.32	.42	.49	.64
						*	*	*	*
AVERAGE	24	5	37.11	36.76	36.26	36.26	36.16	36.13	36.07
			.33	.30	.50	.14	.06	.16	.23
HIGH	24	4	37.22	37.00	36.70	36.38	36.17	36.10	36.04
			.16	.12	.10	.13	.25	.28	.31

values are means and standard deviations; Tw is water temperature;
* is N = N-1

Table 8. Rectal temperature values during exercise in water at equivalent thermal strain (A) and equal thermal stress (B) for low, average, and high body fat groups.

A

	Tw	N	PRE	30	60	90	120	150	180
LOW	26	5	37.03	36.88	36.82	36.56	36.85	36.84	36.82
			.21	.33	.51	.73	.58	.56	.52
AVERAGE	22	5	37.18	36.78	36.66	36.6	36.57	36.47	36.50
			.32	.26	.22	.29	.37	.46	.67
HIGH	18	4	37.03	37.27	37.21	36.97	36.86	36.72	36.58
			.08	.17	.11	.21	.20	.32	.45

B

	Tw	N	PRE	30	60	90	120	150	180
LOW	24	5	37.05	36.70	36.57	36.60	36.72	36.65	36.63
			.08	.20	.26	.42	.67	.74	.68
AVERAGE	24	5	37.00	36.56	36.64	36.63	36.72	36.75	36.77
			.19	.38	.40	.43	.49	.54	.60
HIGH	24	4	37.03	37.26	37.38	37.34	37.25	37.24	37.25
			.10	.15	.38	.48	.48	.42	.39

values are means and standard deviations; Tw is water temperature;
* is N = N-1

Table 9. Esophageal temperature values during rest in water at equivalent thermal strain (A) and equal thermal stress (B) for low, average, and high body fat groups.

A

	Tw	N	PRE	30	60	90	120	150	180
LOW	26	5	36.88	36.8	36.54	36.42	36.4	36.38	36.41
			.22	.29	.34	.20	.15	.15	.28
AVERAGE	22	3	36.70	36.86	36.50	36.40	36.30	36.28	36.27
			.21	.16	.24	.03	.21	.18	.18
									*
HIGH	18	3	36.76	36.87	36.51	36.36	36.15	36.16	36.36
			.17	.18	.12	.10	.23	.28	.21

B

	Tw	N	PRE	30	60	90	120	150	180
LOW	24	5	38.83	36.87	36.33	36.09	36.25	36.31	36.30
			.22	.3	.42	.49	.37	.35	.36
AVERAGE	24	3	36.71	36.68	36.51	36.35	36.53	36.43	36.56
			.22	.27	.23	.18	.16	.25	.17
HIGH	24	4	36.81	36.81	36.41	36.16	36.04	36.18	36.11
			.06	.08	.10	.10	.26	.20	.28

values are means and standard deviations; Tw is water temperature;
* is N = N-1

Table 10. Esophageal temperature values during exercise in water at equivalent thermal strain (A) and equal thermal stress (B) for low, average, and high body fat groups.

A

	Tw	N	PRE	30	60	90	120	150	180
LOW	26	5	36.74	36.99	36.80	36.82	36.92	36.91	36.87
			.18	.20	.33	.44	.42	.44	.43
AVERAGE	22	3	36.76	36.89	36.87	36.75	36.78	36.83	36.77
			.18	.06	.36	.55	.61	.53	.55
HIGH	18	3	36.67	37.32	37.05	36.86	36.85	36.69	36.53
			.07	.31	.26	.20	.18	.19	.32

B

	Tw	N	PRE	30	60	90	120	150	180
LOW	24	5	36.84	36.87	36.86	36.85	36.90	36.90	36.89
			.14	.37	.39	.45	.60	.65	.71
AVERAGE	24	3	36.71	36.68	36.51	36.35	36.53	36.43	36.56
			.22	.27	.23	.18	.16	.25	.17
HIGH	24	3	36.68	37.29	37.18	37.16	37.10	37.21	37.26
			.07	.08	.14	.22	.28	.25	.22

values are means and standard deviations; Tw is water temperature;
* is N = N-1